SECTION 5 - EQUIVALENT PROCEDURES FOR HELICOPTERS

The objective of a noise certification demonstration test is to acquire data for establishing an accurate and reliable definition of a helicopter's noise characteristics (see section 8.7 of Annex 16, Volume 1). In addition, the Annex establishes a range of test conditions and procedures for adjusting measured data to reference conditions.

5.1 FLIGHT TEST PROCEDURES

5.1.1 **Noise certification guidance**

Noise certification of helicopters has been required fairly recently and many applicants may find that the current standards and procedures differ from those that they have used hitherto. The following paragraphs are designed to provide clarification of the requirements as set out in Chapter 8 and Appendix 2 of Annex 16, Volume 1.

5.1.1.1 *Helicopter test window for zero adjustment for atmospheric attenuation*

5.1.1.1.1 There is currently a "test window" contained in Annex 16, Volume 1 (paragraph 2.2.2 of Appendix 2) which needs to be met before test results are acceptable to certificating authorities. In addition if the test conditions fall within a “zero attenuation adjustment window” (Figure 16) defined as the area enclosed by 2°C, 95% RH; 30°C, 95%RH; 30°C, 35% RH; 15°C, 50% RH; and 2°C, 90% RH, the atmospheric attenuation adjustment of the test data may be taken as zero. That is the terms $0.01\left[a(i) - a(i)_0\right]QK$ and $0.01a(i)_0\left(QK - Q_r K_r\right)$ from the equation for $SPL(i)_r$ in paragraph 8.3.1 of Appendix 2 of Annex 16, Volume 1, become zero and the adjustment becomes:

$$SPL(i)_r = SPL(i) + 20\log\left(QK/Q_r K_r\right)$$

In addition, provided that <u>all</u> the measured points for a particular flight condition are within the “zero attenuation adjustment window” defined in Figure 16 and are within the appropriate height tolerances for flyover of ±9 m (±29.5 ft), for approach ±10 m (±32.8 ft) and the 2 EPNdB limit on the take-off adjustment for height given in paragraph 8.7.4a of Chapter 8 of Annex 16, Volume 1, the ratios of the reference and test slant distances for the propagation path adjustments may be replaced by the ratios of the reference and test distances to the helicopter when it is over the centre noise measuring point.

The total effect of both simplifications is that the equation of paragraph 8.3.1 of Appendix 2 of Annex 16, Volume 1 becomes:

$$SPL(i)_r = SPL(i) + 20\log\left(HK/H_r K_r\right)$$

and the duration adjustment specified in paragraph 8.4.2 of Appendix 2 of Annex 16, Volume 1, becomes:

$$\Delta_2 = -7.5\log\left(HK/H_r K_r\right) + 10\log\left(V/V_r\right)$$

where *HK* is the measured distance from the helicopter to the noise measuring point when the helicopter is directly over the centre noise measuring point and H_rK_r is the reference distance.

5.1.1.2 *Helicopter test speed*

5.1.1.2.1 There are two requirements on helicopter test speeds. Firstly, the airspeed during the 10 dB-down time period should be close to, ie. within 9 km/h (5 kt), of the reference speed (see 8.7.6 of Volume 1 of Annex 16) to minimise speed adjustments for the three certification conditions of take-off, flyover and approach.

5.1.1.2.2 The second speed requirement applies to the flyover case (see 8.7.7 of Volume 1 of Annex 16). When the absolute wind speed component in the direction of flight exceeds 9 km/h (5 kt) the level overflights shall be made in equal numbers with a head wind component and tail wind component. The objective is to counter the effect of the short duration correction obtained in the downwind direction with the larger one into wind. In steady wind conditions the net effect of flying into and with the wind would be zero.

5.1.1.2.3 The measurement of groundspeed may be obtained by timing the helicopter as it passes over two points a known distance apart on the helicopter track during the overflight noise measurements. These two points should straddle the noise measurement microphone array.

5.1.1.3 *Test speed for light helicopters*

For the purposes of compliance with Chapter 11 of Annex 16, Volume 1, the helicopter should be flown at test speed V_{ar} which will produce the same advancing blade Mach number as the reference speed in reference conditions given in paragraphs 11.5.1.4 and 11.5.2 b) of Chapter 11 of Annex 16.

The reference advancing blade Mach number M_R is defined as the ratio of the arithmetic sum of the blade tip rotational speed V_{tip} and the helicopter true airspeed V_{REF} divided by the speed of sound, c, at 25 °C (346.1 m/sec) such that:

$$M_R = \frac{V_{TIP} + V_{REF}}{c}$$

The test airspeed V_{AR} is calculated from:

$$V_{AR} = c_T \left(\frac{V_{TIP} + V_{REF}}{c} \right) - V_{TIP}$$

where: c_T is the speed of sound obtained from the onboard measurements of outside air temperature.

Since the ground speed obtained from the overflight tests will differ from that for reference conditions an adjustment Δ_2 of the form:

$$\Delta_2 = 10 \log\left(V_{ar} / V_{ref} \right)$$

will need to be applied. Δ_2 is the increment in decibels that must be added to the measured sound exposure level (SEL).

5.1.1.4 *Helicopter test mass*

The mass of the helicopter during the noise certification demonstration (see 8.7.11 of Volume 1 of Annex 16) must lie within the range 90 per cent - 105 per cent of the maximum take-off mass for the take-off and flyover and between 90 per cent - 105 per cent of the maximum landing mass for the approach demonstration. For noise certification purposes the effect of change of mass is to change the test day flight path for take-off and adjustments to the reference flight path should be made for spherical spreading and atmospheric attenuation as described in section 9 of Appendix 2, Annex 16, Volume 1.

5.1.1.5 *Helicopter approach*

Section 8.7.10 of Chapter 8 in Annex 16 constrains the approach demonstration to within ±0.5° of the reference approach angle of 6°. Adjustments to the reference approach angle are required to account for spherical spreading effects and atmospheric attenuation as described in section 9 of Appendix 2, Annex 16, Volume 1.

5.1.1.6 *Helicopter flight path tracking*

Annex 16, Volume 1, Appendix 2, Section 2.3 requires that the helicopter position relative to the flight path reference point be determined and synchronised adequately with the noise data between the 10 dB-down points.

Methods which have been used include:

a) radar or microwave tracking system;

b) theodolite triangulation; and

c) photographic scaling

These techniques may be used singly or in combination. Practical examples of aircraft tracking systems employing one or more of these techniques, are described below. This material is not intended to be an exhaustive list and additional information will be included as more experience is acquired.

5.1.1.6.1 Radar or microwave tracking system

One example of a radar position tracking system is shown in Figure 14. It operates on a principle of the pulse radar with a radar interrogator (receiver/transmitter) located on the aircraft and a radar transponder (reference/station) positioned at each reference station. The elapsed time between the receiver/transmitter pulse and reception of the pulse returned from the reference station transponder is used as the basis for determining the range of each reference station.

This range information together with the known location of the reference stations can be used to obtain a fix on the position of the aircraft in three dimensions. A pulse coding system is employed to minimise false returns caused by radar interference on reflected signals.

The system performs the following basic functions during noise certification:

a) continuously measures the distance between the helicopter and four fixed ground sites;

b) correlates these ranges with IRIG-B time code and height information and outputs this data to a PCM recorder;

c) converts the aircraft range and height information into X, Y and Z position co-ordinates in real time; and

d) uses the X, Y, Z data to drive a cockpit display providing the pilot with steering and position cueing.

The accuracy of the co-ordinate calculation depends on the flight path and transponder geometry. Errors are minimised when ranges intersect and the recommended practice is to keep the intersection angle near to 90°. The four transponder arrangements shown in Figure 14 produce position uncertainties from ±1.0 to ±2.0 m.

Some inaccuracies at low aircraft heights can be introduced with the use of microwave systems and the use of a radio-altimeter can reduce the errors. The height data is recorded and synchronised with the microwave.

Helicopter equipment: The distance measuring unit computer and transponder beacon are connected to a hemispherical antenna which is mounted under the fuselage, on the aircraft centreline, as close to the helicopter centre of gravity as possible.

Ground equipment: The four beacons are located on either side of the aircraft track to permit the optimum layout, ie. covering the helicopter with angles between 30° and 150° (90° being the ideal angle).

For example, two beacons can be located in the axis of the noise measurement points at ±500 m of central microphone, another two beacons can be located under track at ±600 m from the central microphone.

5.1.1.6.2 Kine-theodolite system

It is possible to obtain helicopter position data with classical kine-theodolites, but it is also possible to make use of a system composed of two simplified theodolites including a motorised photocamera on a moving platform reporting site and elevation. These parameters are synchronised with coded time and the identification number of every photograph recorded.

Each 0.1 s site and elevation data are sent by UHF to a central computer which calculates the helicopter position X, Y, Z, versus time for each trajectory.

Photography stations are located at sideline positions, about 300 m from the track, and at 200 m either side of the 3 noise measurement points.

The accuracy of such a system can be ±1.5 m in (X, Y, Z) over the working area.

5.1.1.6.3 Radar/theodolite triangulation

The opto-electronic system shown diagramatically in Figure 15 uses a single optical theodolite to provide azimuth and elevation while range data are obtained from a radar tracking system using a single transponder. Data from these two sources are transferred to a desk top calculator at a rate of 20 samples/second from which three dimensional position fixes can be derived. The system also provides tape start and stop times to the measuring sites, synchronising all tape recording times. Accuracy of the system is approximately ±2.0 m, ±1.0 m and ±2.0 m for horizontal range (x), cross-track (y) and height (z) respectively. Uncertainties associated with determination of the visual glide slope indicator and ground speed are ±0.1° and ±0.5 kt.

5.1.1.6.4 Photographic scaling

The flight path of the helicopter during the noise certification demonstration may be determined by the use of a combination of ground based cameras and height data supplied as a function of time from the on-board radio or pressure altimeters.

In this method three cameras are placed along the intended track such that one is sited close to the centre microphone position and the other two sited close to each of the 10 dB-down points typically 500 m either side of the microphone, depending upon the flight procedure being used. The cameras are mounted vertically and are calibrated so that the image size, obtained as the helicopter passes overhead, can be used to determine the height of the aircraft. It is important that the time at which each camera fires is synchronised with the on-board data acquisition system so that the height of the aircraft as it passes over each of the cameras, can be correlated with the heights obtained from the photographs.

The flight path of the helicopter as a function of distance may be obtained by fitting the aircraft data to the camera heights.

The aircraft reference dimension should be as large as possible to maximise photograph image size but should be chosen and used with care if errors in aircraft position are to be avoided. Foreshortening of the image due to main rotor coning (bending of the blades), disc tilt or fuselage pitch attitude if not accounted for will result in over estimates of height, lateral and longitudinal offsets.

By erecting a line above each of the cameras at right angles to the intended track, at a sufficient height above the camera to provide a clear photographic image of both the line and the helicopter, the applicant may obtain the lateral offset of the helicopter as it passes over each of the cameras. This can be done by attaching marks to the line showing the angular distances from overhead at 5° intervals either side of the vertical.

This method may be used to confirm that the helicopter follows a 6° ±0.5° glideslope within 10° of overhead the centre microphone as required by Annex 16, Volume 1, Chapter 8, paragraph 8.7.10 and 8.7.8.

Further, from the synchronised times of the helicopter passing over the three camera positions the ground speed can be determined for later use in the duration correction adjustment.

Overall accuracy of the system is ±1.0 per cent of height and ±1.3 per cent of longitudinal and lateral displacements. Mean approach/climb angles and mean ground speed can be determined within ±0.25° and ±0.7 per cent respectively.

5.1.1.7 *Atmospheric test conditions*

The temperature, relative humidity and wind velocity limitations are contained in Appendix 2 of Annex 16, Volume 1 (see 2.2.2). The parameters are measured at 10 m (33 ft). For adjustment purposes the measured values of these parameters are assumed to be representative of the air mass between the helicopter and the microphones. No calculation procedures based on the division of the atmosphere into layers are required, but such a method of analysis could be accepted by the certificating authority.

5.1.1.8 *Procedure for the determination of source noise correction*

5.1.1.8.1 For the demonstration of overflight reference noise certification levels off-reference adjustments shall normally be made using a sensitivity curve of PNLTM versus advancing blade tip Mach number deduced from flyovers carried out at different airspeeds around the reference airspeed; however, the adjustment may be made using an alternative parameter, or, parameters, approved by the certificating authority. If the test aircraft is unable to attain the reference value of advancing blade tip Mach number or the agreed reference noise correlating parameter, then an extrapolation of the sensitivity curve is permitted providing that the data cover a range of values of the noise correlating parameter agreed by the certificating authority between test and reference conditions. The advancing blade tip Mach number or agreed noise correlating parameter shall be computed from as measured data using true airspeed, onboard outside air temperature (OAT) and rotor speed. A separate curve of source noise versus advancing blade tip mach number or another agreed noise correlating parameter shall be derived for each of the three certification microphone locations i.e. centreline, sideline left and sideline right. Sidelines left and right are defined relative to the direction of the flight on each run. PNLTM adjustments are to be applied to each microphone datum using the appropriate PNLTM function.

5.1.1.8.2 In order to eliminate the need for a separate source noise correction to the overflight test results the following test procedure is considered acceptable when the correlating parameter is the main rotor advancing blade tip Mach number.

Each overflight noise test must be conducted such that:

a) The reference airspeed (V_R) specified in Section 8.6.3 of Chapter 8 of Annex 16, Volume 1, with such airspeed adjusted as necessary to produce the same main rotor advancing blade tip Mach number as associated with reference conditions;

Note: The reference advancing blade tip Mach number (M_R) is defined as the ratio of the arithmetic sum of the main rotor blade tip rotational speed (V_{TIP}) and the helicopter reference speed (V_R) divided by the speed of sound (c) at 25 ° C (346.1 m/s) such that :

$$M_R = \frac{V_{TIP} + V_{REF}}{c},$$

and the adjusted reference airspeed ((V_{AR}) is calculated from:

$$V_{AR} = c_T\left(\frac{V_{TIP} + V_{REF}}{c}\right) - V_{TIP},$$

where c_T is speed of sound from the onboard measurement of outside air temperature (see Paragraph 6.7).

b) The test true airspeed (V) shall not vary from the adjusted reference true airspeed (V_{AR}) by more than ±5 km/h (±3 kt) or an equivalent approved variation from the reference main rotor advancing blade tip Mach number; and

c) The onboard outside static air temperature must be measured at the overflight height just prior to each flyover.

The calculation of noise levels, including the corrections, is the same as that described in Chapter 8 and Appendix 2 of Annex 16, Volume 1, except that the need for source noise adjustment is eliminated. It should be emphasised that in the determination of the duration correction (Δ_2), the speed adjustment to the duration correction is calculated as 10 log(V_g/V_{g_R}), where V_g is the test ground speed and V_{g_R} is the reference ground speed.

5.1.2 **On board flight data acquisition**

5.1.2.1 It is necessary to obtain the values of a variety of flight and engine parameters during the noise measurement period in order to:

a) determine the acceptability of helicopter noise certification flight tests;

b) obtain data to adjust noise data; and

c) to synchronise flight, engine and noise data.

Typical parameters would include airspeed, height/altitude, rotor speed, torque, time etc.

5.1.2.2 A number of methods for collecting this information have been employed:

a) manual recording;

b) magnetic tape recording;

c) automatic still photographic recording;

d) cine recording; and

e) video recording.

5.1.2.3 Clearly, when a large number of parameters are required to be collected at relatively short time intervals, it may not be practicable to manually record the data and the use of one of the automatic systems listed as 5.1.2.2 b) to e) becomes more appropriate. The choice of a particular system may be influenced by a number of factors such as the space available, cost, availability of equipment etc.

5.1.2.4 For systems which optically record the flight deck instruments (5.1.2.2 c) to e)) care must be taken to avoid strong lighting contrast, such as would be caused by sunlight and deep shadow, and reflections from the glass fronts of instruments which would make data unreadable. To avoid this it may be necessary to provide additional lighting to "fill in" deep shadow regions. To prevent reflections from the front of instruments it is recommended that light coloured equipment or clothing on the flight deck is avoided. Flight crews should be required to wear black or dark coloured clothing and gloves.

5.1.2.5 Further, for systems which record the readings of dials it is important that the recording device is as near as possible directly in front of the instruments to avoid parallax errors.

5.1.2.6 *Magnetic tape recording*

Multi-channel instrumentation tape recorders designed for airborne environments are employed for continuous recording of flight and engine performance parameters. Typical recorders are compact intermediate/wide band and can take both ½ and 1" magnetic tapes with a 24 to 28 Volt DC power requirements. Six tape speeds and both direct and FM recording are available in a tape recorder weighing about 27 kg.

5.1.2.7 *Automatic still photographic recording*

Photographs of the flight deck instrument panel can be taken using a hand held 35 mm SLR camera with an 85 mm lens and high speed slide film. The indications on the instruments can be read by projecting the slides onto a screen.

5.1.2.8 *Cine recording*

Cine cameras with a one frame per second exposure rate have been used to acquire flight deck data. Care must be taken in mounting the camera to ensure that all the instruments required to be photographed are within the field of view. Typical film cassettes containing about 2000 frames have been used with a frame counter to allow film changes to be anticipated.

5.1.2.9 *Video recording*

Flight and engine performance parameters can be recorded with a video camera, although as with cine cameras, care must be taken to ensure that all the instruments required are within the field of view. The recorded information is played back using freeze frame features to obtain individual instrument readings.

5.1.2.10 *Time synchronisation of recorded data*

The need to synchronise the noise recordings with the on board recorded flight deck data is important. This will involve radio communication between the helicopter and the noise recording positions. Several methods have been used such as noting the synchronisation time on a clock mounted on the instrument panel which itself is recorded by the data acquisition system. One such system uses a ground camera which operates a radio transmission which, when received by the helicopter lights two high intensity LED's mounted in an analogue clock attached to the instrument panel.

5.1.3 **Procedures for the determination of changes in noise levels**

Noise level changes determined by comparison of flight test data for different helicopter model series have been used to establish certification noise levels of modified or newly derived versions by reference to the noise levels of the baseline or "flight datum" helicopter model. These noise changes are added to or subtracted from the noise levels obtained from individual flights of the "flight datum" helicopter model. Confidence intervals of new data are statistically combined with the "flight datum" data to develop overall confidence intervals (see Appendix 1).

5.1.3.1 *Modifications or upgrades involving aerodynamic drag changes*

Use of drag devices, such as drag plates mounted beneath or on the sides of the "flight datum" helicopter, has proved to be effective in noise certification of modifications or upgrades involving aerodynamic drag changes. External modifications of this type are made by manufacturers and aircraft "modifiers". Considerable cost savings are realised by not having to perform noise testing of numerous individual modifications to the same model series.

Based on these findings it is considered acceptable to use the following as an equivalent procedure:

a) For helicopters to be certificated under Chapter 8 or Chapter 11 of Annex 16, Volume 1, a drag device is used that produces the aerodynamic drag calculated for the highest drag modification or combination of modifications;

b) With the drag producing device installed, a flyover test and take-off and/or approach test if considered appropriate by the certificating authority, in the case of a Chapter 8 certification, or flyover for the case of a Chapter 11 certification, are performed using the appropriate noise certification reference and test procedures;

c) A relationship of noise level versus change in aerodynamic drag or airspeed is developed using noise data, adjusted as specified in Appendix 2 or 4 of Annex 16, Volume 1, of the "flight datum" helicopter and of the "high drag" configuration;

d) The actual airspeed of the modification to be certificated is determined from performance flight testing of the baseline helicopter with the modification installed; and

e) Using the measured airspeed of the modification, certification noise levels are determined by interpolation of the relationship developed in c) above.

5.1.4 **Temperature and Relative Humidity Measurements**

5.1.4.1 Temperature and relative humidity measurements as defined in paragraph 2.2.3 of Appendix 2, Annex 16, Volume 1, are required to be made at a height of 10 m (33 ft) above the ground. The measured values are used in the adjustment of the measured one-third octave band sound pressure levels to account for the difference in the sound attenuation coefficients in the test and reference atmospheric conditions as given in paragraph 8.3.1 of Appendix 2, Annex 16, Volume 1. The distances QK and Q_rK_r in the equations of paragraph 8.3.1 refer to the distances between positions on the measured and reference flight paths corresponding to the apparent PNLTM position and the noise measurement point.

5.1.4.2 As a consequence the procedure assumes that the difference between the temperature and relative humidity at 10 m and the PNLTM position is zero or small and that the atmosphere can be represented by the values measured at 10 m (33 ft) above the ground in the vicinity of the noise measurement point. Data obtained from European and U.S. certification tests over a number of years, and records provided by the U.K. Meteorological Office, have confirmed this assumption is valid over a wide range of meteorological conditions.

~~5.1.4.3 An examination of such conditions has shown that the temperature and relative humidity at altitude corresponding to the PNLTM point differs, in the worst case, from that at 10 m (33 ft) by -3°C (-5.5°F) and +5% relative humidity respectively. Under these conditions the adjustments in paragraph 8.3.1 of Appendix 2, Annex 16, Volume 1, within the allowable temperature and relative humidity test window calculated using meteorological conditions at 10 m (33 ft), will differ from those made using the average of the temperature and relative humidity between 10 m (33 ft) and the PNLTM point by less than 0.1 dB.~~

5.1.4.~~3~~4 Noise certification measurements made under test conditions where ~~greater~~ significant changes in temperature and/or relative humidity with height are ~~likely~~expected, particularly when a significant drop in humidity with altitude is expected, should be adjusted using the average of the temperature and relative humidity measured at 10 m (33 ft) and at the height associated with the PNLTM point in order to eliminate errors associated by use of ~~date~~ data measured at 10 m (33 ft) only. Such special conditions might be encountered in desert areas shortly after sunrise where the temperature near the ground is lower, and the relative humidity considerable higher, than at the height associated with the PNLTM point. Except for tests made under such conditions experience from noise certification tests over many years clearly indicates that the calculations of paragraph 8.3.1 of Appendix 2 of Annex 16, Volume 1, can be based on meteorological data measured at 10 m (33 ft) only.

5.1.5 **Anomalous Test Conditions**

5.1.~~4.5~~5.1 Annex 16, Volume 1, Appendix 2, Paragraph 2.2.2(f) requires that the tests be conducted under conditions that no anomalous meteorological conditions exist. The presence of anomalous atmospheric conditions can be determined to a sufficient level of certainty by monitoring the outside air temperature (OAT) using the aircraft instruments.

Anomalous conditions which could impact the measured levels can be expected to exist when the OAT at 150 m (492 ft) is 2°C (3.2°F) or more than the temperature measured at 10 m (33 ft) above ground level. This check can be made in level flight at a height of 150 m (492 ft) within ~~25~~30 minutes of each noise measurement.

5.1.~~4.6~~5.2 Since the actual heights associated with the PNLTM points will not be known until the analysis is made, measurements of temperature and relative humidity can be made at a number of heights and the actual value determined from a chart of temperature and relative humidity versus height. Alternatively since the influence of height is small, measurements at a fixed height, in the order of 120 m (400 ft) and 150 m (492 ft) depending on the flight condition and agreed with the certificating authority prior to the tests being conducted can be used.

5.1.5.3 If tests are adjusted using the “average” of the temperature and relative humidity measured at 10 m (33 ft) and the height association with the PNLTM point described in 5.1.4.4, the provisions of 5.1.5.1 do not apply. This is because the impact of any anomalous meteorological conditions are taken into account by using the average of the temperature and relative humidity at 10 m (33 ft) and the height associated with the PNLTM point.